

TEXTILE ANTIMICROBIAL TESTING AND STANDARDS

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ABSTRACT

In the hierarchy of human needs, clothing ranks second top most priority next to food. The use of textile for clothing known to mankind from primitive age was gradually extended to household and domestic applications with progressive civilizations. Clothing which served mere protection has changed to “Health Based Clothing”. Now, there is a good deal of demand for the fabrics having functional /speciality finishes in general but antimicrobial finishes in particular to protect human being against microbes is the need of the hour. The application of antimicrobial textile finishes include a wide range of textile products for medical, technical, industrial, home furnishing and apparel sectors. At present there are lots of potential in antimicrobial finish application on textiles. This paper summarizes a comprehensive view of antimicrobial finishing and the required standard assessment.

KEYWORDS: Antimicrobial, Finish, Test Methods, Standards

INTRODUCTION

Microbes such as bacteria, viruses, fungi and yeast are present almost everywhere. Human beings have an immune system to protect against accumulation of microorganisms but material such as textiles can easily be colonised by high numbers of microbes or even decomposed by them. Textiles are carriers of microorganisms such as pathogenic bacteria, odour- generating bacteria, mould and fungi. Antimicrobials enhance the functionality and value of textile products by keeping the microorganisms that cause odour and fibre degradation under control [1].

Antimicrobial fabrics are not only important in medical application but also in daily use conditions [2]. There is a great demand for antimicrobial textiles based on ecofriendly agents which not only help to reduce effectively the ill effects associated due to microbial growth on textile material but also comply with statutory requirements imposed by regulating agencies [3]. But recently there are lot of attraction towards natural based herbs as an antimicrobial agent because of its eco friendly and health hazardless [4]. Though the use of antimicrobials have been known for the decades, it is only the recent couple of years, several attempts have been made on finishing textiles with antimicrobial compounds. Antimicrobial finish prevents the growth of bacteria, health protecting, preventing diseases [5]. Clothing and textile materials are not only the carriers of microorganisms such as pathogenic bacteria, odour generating bacteria and mould fungi, but also good media for the growth of the microorganisms. Among various functional ability the antimicrobial property of fabric is being considered to be important with garments, which are in direct contact with human body [6].

TEXTILE ANTIMICROBIAL FINISHES

Terminology

Activity – (of an antimicrobial agent) a measure of effectiveness of the agent.

Antibacterial agent – any chemical which kills bacteria (bactericide) or interferes with the multiplication, growth or activity of bacteria (bacteriostat)[7]

Antifungal agent – any chemical which kills or inhibits the growth of fungi

Antimicrobial – drugs that act against a variety of microorganisms

Antimicrobial agent – any chemical which kills or inhibits the growth of microorganisms.

Zone of inhibition – clear area of no growth of a microorganism, cultured onto the surface of agar growth medium, in proximity to the borders of a specimen placed in direct contact with this agar surface [8].

Antimicrobial Agents

All antibacterial agents, when applied to textiles, do not work in a similar manner and their behaviour towards the microorganisms varies from one to the other agents. Alive bacteria or fungus generally has a cell wall which protects it from the adversity of the outer environment. This cell wall or membrane is made of mainly polysaccharides. The cell holds the body of the microorganism which consists of other components such as a variety of enzymes and nucleic acids. Obviously, the cell wall maintains the metabolism of the cell and plays a vital role in maintaining the integrity of the particular microbe. Thus the mortality or growth of the cell depends on the cell wall to a great extent.

Antimicrobial Modes of Action

Most of the antibacterial agents work under two main principles: inhibition of the growth of the cells (biostatic) and killing of the cell (biocidal). Almost all the commercial antimicrobial agents are biocides. They damage the cell wall or inhibit the metabolism of the cell by stopping nutrient penetration inside the cell; both are necessary for the survival of the cell[9].

The degree of activity is denoted by:

«-cidal»: agent that kill microorganisms

«-static»: agents that inhibits microorganisms growth i.e. their number remains the same.

Example: When the microorganism is killed the suffix“cide”“Bactericide” and when the growth is stopped the suffix “static” is used e.g “Bacteriostatic” [10].



Figure 1: Bacteriostatic vs Bactericide

History of Antimicrobial Finishes

Application of natural antimicrobial agents on textiles dates back to antiquity, when the ancient Egyptians used spices and herbs to preserve mummy wraps. Herbs were used to inhibit the growth of bacteria on textiles [11]. The use of

antimicrobials dates back to ancient Egypt where these were used in the procurement of mummies. The first antimicrobial textile material, in modern history, was developed by Lister in 1867. Over the last few years there has been increased interest in antimicrobial finishes [12]. The concern and need for protection against micro-organisms during World War II, began the research race to find or make a suitable antimicrobial finish. One of the first antimicrobial finish used during World War II was made to prevent cotton textiles such as tents, tarpaulins and vehicle covers from rotting [13].

Essentials of Antimicrobial Finishes

Antimicrobial treatment for textile materials is necessary to:

- Avoid cross infection by pathogenic microorganisms.
- Control the infestation by microbes.
- Arrest metabolism in microbes in order to reduce the formation odour.
- Safeguard the textile products from staining, discoloration and quality deterioration[14] .
- Limit the growth of the bacterial colonies to their extinction.
- Prevent the microbial attack on it and to prolong their useful life [15].
- Protect the textile user against pathogenic or odour causing microorganisms.
- Guard the textile itself from damage caused by mould, mildew or rot producing microorganisms [16].

Requirements for Textile Antimicrobial Finishes

Antimicrobial textile finishes must exhibit:

- Effective control of bacteria, molds and fungi
- Selective activity towards undesirable microorganisms
- Absence of toxic effects for both the manufacturer and the consumer
- Durability of activity to laundering, dry cleaning, leaching
- Applicability with no adverse effects on the fabric
- Acceptable moisture transport properties
- Compatibility with other finishing agents
- Easy application, compatibility with common textile processing [14].

Properties of an Effective Antimicrobial Finish

An effective Antimicrobial finish should possess the following properties:

- Antimicrobial finish must act quickly to be effective, because the growth rates of microbes are rapid
- The antimicrobial must kill or stop the growth of microbes and must maintain this property through cleaning cycles or outdoor exposure
- The antimicrobial must be safe for the manufacturer to apply and consumer to wear

- The finish must meet strict government regulations and have a minimal environment impact
- The antimicrobial finish must be easy to apply and should be compatible with other finishing agents
- The antimicrobial finish should have no adverse effects on the other fabric properties including wear comfort
- The antimicrobial finish should be of low cost [16].

Characteristics of Antimicrobial Agents for Textiles

Antimicrobial agents can be considered as textile antimicrobial agents if they have the following characteristics:

Stability

Stability is determined by resistance to heat, light, ultraviolet rays and oxidizing agents. Very few chemical compounds possess all the characteristics. The agent must be stable as a compound and also when applied to the fabric. It must be stable not only for the estimated life of the finished goods, but must retain its stability through long period of storage.

Efficacy

The efficacy may be bacteriostatic/fungistatic or bactericidal/fungicidal. A large number of products actually destroy the microbes before they can grow and damage the fabric. Moreover, the compounds must be effective at a relatively small percentage, so as to enable the user to retain low weight add-on, and also to keep the cost within reasonable limits.

Toxicity

It must be non-toxic or of an extremely low order of toxicity. This is the most essential requirement of a good antimicrobial agent.

Odour

The antimicrobial compounds must not impart an unpleasant odour to the end item, particularly if it falls into the wear-apparel class. A number of antimicrobial agents possess unpleasant odour characteristics, while others are entirely free from this objectionable feature.

Colour

If the colour is of importance to the sale of the product, the antimicrobial agent must not discolour the treated material. This characteristic presents no great obstacle, since dye adjustments easily overcome any colour changes caused by these agents.

Hand

The antimicrobial agent must not significantly change the hand of the fabric, especially if the fabric is to be used in the manufacture of wearing apparel. Fabric should not get harsh hand after-treatment from antimicrobial agent.

Chemical Effects

The antimicrobial agent must have no adverse chemical effects on the fabric processed. The tensile strength of the fabric must be maintained through long periods of use under all types of conditions [17].

ANTIMICROBIAL APPLICATION

The antimicrobial agents can be applied to the textile substrates by exhaust, pad-dry-cure, coating, spray and foam techniques. The substances can also be applied by directly adding into the fibre spinning dope. The antimicrobial finishes are generally applied by following means to the textile substrate:

- Insolubilisation of the active substances in/on the fibre.
- Treating the fibre with resin, condensates or cross-linking agents.
- Micro encapsulation of the antimicrobial agents with the fibre matrix.
- Coating on the fibre surface.
- Chemical modification of the fibre by covalent bond formation.
- Use of graft polymers, homo polymers and/or co-polymerization on to the fibre [17].

ANTIMICROBIAL TESTING

Testing is a valuable aid for textile production, distribution, and consumption. Textiles directly get into touch with our bodies, and so testing for such chemical compounds which affect the health (specifically skin) of an individual is crucial, and this becomes even more important for infants and children whose skins are far more sensitive than that of adults [18]. Textile testing will definitely help in evaluating the effectiveness of antibacterial finishes and also can be used to conclude about the quality of end products and their extent of microbial resistance [19]. To measure the efficacy of antimicrobially treated textiles, test methods used under controlled conditions for reproducible results are needed [20]. The antimicrobial activities are generally tested both qualitatively and quantitatively through standard tests. Some of available standards are as follows:

AATCC Standards

AATCC 100-2004 Assessment of Antibacterial Finishes on Textile Materials

The test microorganism is grown in liquid culture. The concentration of the test microorganism is standardized. The microbial culture is diluted in a sterile nutritive solution. Control and test fabric swatches are inoculated with microorganisms. The inoculation is performed such that the microbial suspension touches only the fabric. Bacteria levels on both control and test fabrics are determined at "time zero" by elution in a large volume of neutralizing broth, followed by dilution and plating. A control is run to verify that the neutralization/elution method effectively neutralizes the antimicrobial agent in the fabric. Additional inoculated control and test fabrics are allowed to incubate, undisturbed in sealed jars, for 24 hours. After incubation, microbial concentrations are determined. Reduction of microorganisms relative to initial concentrations and the control fabric is calculated [19].

Percent reduction of bacteria by the specimen treatments was calculated using following formula [21]:

$$R = 100 (B - A) / B$$

where: R is % reduction

A is the number of bacteria recovered from the inoculated treated test specimen swatches in the jar incubated over desired contact period

B is the number of bacteria recovered from the inoculated treated test specimen swatches in the jar immediately after inoculation (at “0” contact time).

AATTC Test Method 147-2004 Parallel Streak Method [6]

Specimens of the test material including corresponding untreated controls of the same material are placed in intimate contact with the agar surface which has been previously streaked with an inoculum of a test bacterium. After incubation a clear area of interrupted growth underneath and along the sides of test material indicates antibacterial activity of the specimen. A standard strain of bacteria is used which is specific to the requirements of the material under test.

The average width of a zone of inhibition along a streak on either side of the test specimen was calculated using the following equation:

$$W = (T - D)/2$$

where: W is width of clear zone of inhibition in mm

T is total diameter test specimen and clear zone in mm

D is diameter of the test specimen in mm.

AATTC Test Method 30-2004 Antifungal Activity, Assessment on Textile Materials: Mildew and Rot Resistance of Textiles

Test I Soil Burial Test - Only those specimens that will come in direct contact with soil such as sandbags, tarpaulins, tents need to be tested by this procedure.

Test II Agar Plate Test, *Chaetomium globosum* - This procedure is used for evaluating rot resistance of cellulose containing textile materials that will not come in contact with soil. It may also be used for determining uniformity of fungicide treatment.

Test III Agar Plate Test, *Aspergillus niger* – Certain fungi, of which *Aspergillus niger* is one, can grow on textile products without causing measurable breaking strength loss within a laboratory experimental time frame. Nonetheless, their growth may produce undesirable and unsightly effects. This procedure is used to evaluate textile specimens where growth of these fungi is important [22].

Test IV Humidity Jar, Mixed Spore Suspension

In AATCC TM30 (Test IV), a dry, treated and untreated 1 × 3 inches strip of nutrient saturated fabric, sprayed with a mixed-spore suspension of mildew causing organisms, is suspended and incubated in a closed jar with sterile water in the bottom to provide moist conditions. After the incubation period, the percent fungal growth is graded. The organism must germinate and establish itself on the treated fabric, whereas in the Test III test, the agar provides an antimicrobial-free zone for the fungus to establish itself and then overgrow the sample. Thus, the Test IV method is less aggressive than the Test III method and allows for somewhat better discrimination between treated and untreated samples [23].

AATTC Test Method 174-2011 Antimicrobial Activity Assessment of Carpets [7]

Qualitative Assessment of Antimicrobial Activity Assessment of Carpets: Single Streak Method

Specimens of the test material including corresponding untreated controls of the same material are placed in intimate contact with the agar surface which has been previously streaked with a bacterial culture. After incubation a clear

area of interrupted growth underneath and along the sides of test material indicates antibacterial activity of the specimen. Standard strains of bacteria is with *Staphylococcus aureus* (Gram positive) and *Klebsiella pneumonia* (Gram negative), the representative organisms.

The average width of a zone of inhibition along a streak on either side of the test specimen was calculated using the following equation ⁶:

$$W = (T - D)/2$$

where: W is width of clear zone of inhibition in mm

T is total diameter test specimen and clear zone in mm

D is diameter of the test specimen in mm.

Quantitative Assessment of Antimicrobial Activity Assessment of Carpets

Test carpets are inoculated with test organisms. After incubation the bacteria are eluted from swatches by shaking in known amounts of liquid. The number of bacteria present in this liquid is determined and the percent reduction by the specimen is calculated.

Percent reduction of bacteria by the specimen treatments can be calculated using one of the formulas ⁷:

$$R = 100 (B - A)/B$$

$$R = 100 (C - A)/C$$

$$R = 100 (D - A/D)$$

where: R is % reduction

A is the number of bacteria recovered from the inoculated treated test carpet in the jar incubated over desired contact period

B is the number of bacteria recovered from the inoculated treated test carpet in the jar immediately after inoculation (at “0” contact time).

C is the number of bacteria recovered from the inoculated untreated control carpet in the jar immediately after inoculation (at “0” contact time).

$$D = (B + C)/2$$

Antifungal Activity Assessment of Antimicrobial Activity Assessment of Carpets

The carpet is subjected to the growth of a common fungus on a nutrient agar medium.

Evaluation and Scoring is given as follows:

Observed Growth

0 = No growth (if present, report the size of the growth free zone in mm)

1 = Microscopic growth (visible only under the microscope)

2 = Macroscopic growth (visible to the eye)

AATCC Test Method 90-2011 Antibacterial Activity Assessment of Textile Materials: Agar Plate Method [24]

Specimens of the test material including corresponding untreated controls of the same material are placed in intimate contact with the agar which has been previously seeded with an inoculum of a test bacterium. After incubation a clear area of interrupted growth underneath and/or adjacent to the test material indicates antibacterial activity of the specimen. A standard strain of bacteria is used that is specific to the requirements of the material under test.

The average width of a zone of inhibition on either side of the test specimen may be calculated using the following equation.

$$W = (T - D)/2$$

where: W is width of clear zone of inhibition in mm

T is total diameter test specimen and clear zone in mm

D is diameter of the test specimen in mm.

Table 1: Comparison between Different AATCC Test Methods [13]

AATCC Test Method	Comments
Antibacterial activity of textile materials: parallel streak method; test method 147-2004 (agar plate test)	Rapid qualitative method for determining antibacterial activity of treated textile materials against both Gram-positive and Gram-negative bacteria. Treated material is placed in nutrient agar that is streaked with test bacteria. Bacterial growth is determined visually after incubation. Antibacterial activity is demonstrated by zones of inhibition on and around the textile.
Antibacterial finishes on textile materials, assessment of: test method 100 -2004	Quantitative method for determining the degree of antimicrobial activity of treated textiles. The amount of bacterial growth in inoculated and incubated textiles is determined through serial dilutions and subsequent inoculations of sterile agar. Gram positive and Gram-negative bacteria are used.
Antifungal activity, assessment on textile materials: mildew and rot resistance of textiles; test method 30-2004	Four methods for determining the antifungal assessment on textile properties of treated textiles. One method involves testing fabric properties after burial in soil that contains fungi. In a second method, cellulose fabric is textiles; exposed to <i>Chaetomium globosum</i> in an agar plate and the subsequent growth visually determined. <ul style="list-style-type: none"> The third method exposes textiles to <i>Aspergillus niger</i> in an agar plate and visually determines any fungal growth. The fourth method uses a humidity jar to expose textiles to mixture of fungi spores. Any growth on the textile is visually determined.
Antimicrobial activity assessment of carpets; test method 174-2011	Methods are given for the qualitative and quantitative determination of antibacterial activity and the qualitative evaluation of antifungal properties of carpet samples using procedures and materials similar to those in the above test methods.

Various Other Standards

- SN 195920 Textile Fabrics: Determination of antimicrobial activity: Agar diffusion plate test
- SN 195921 Textile Fabrics: Determination of antimycotic activity: Agar diffusion plate test
- SN 195924 Textile Fabrics- Determination of the antibacterial activity: Germ Count Method
- JIS L 1902 / ISO 20743 Testing for antibacterial activity and efficacy on textile products
- JIS Z 2801 Test for Antimicrobial Activity of Plastics

- BS EN ISO 20645: Determination of antibacterial activity: Agar diffusion Plate test
- BS EN ISO 11721-1: Determination of resistance of cellulose-containing textiles to micro-organisms- Soil Burial Test – Assessment of rot-retardant finishing
- BS EN ISO 11721-2: Determination of resistance of cellulose-containing textiles to micro-organisms- Soil Burial Test– Identification of long-term resistance of a rot-retardant finish
- ASTM D 4300 : Antimicrobial Testing for ability of adhesive Films to support or resist the growth of Fungi
- ASTM E2149 : Determining the Antimicrobial Activity of Immobilized Antimicrobial Agents under Dynamic Contact Conditions
- ASTM E2180 : Determining the activity of Incorporated Antimicrobial Agents in Polymeric or Hydrophobic Materials
- ASTM G21: Determining Resistance of Synthetic Polymeric Materials to Fungi [19]

CONCLUSIONS

We usually think about textiles to be the clothes we wear but it has changed its trend to functional one. Market research shows that most of us are very conscious about our hygiene and cleanliness. Therefore, textile finishes with added value particularly for medical clothes are greatly appreciated and there is an increasing demand on global scale. The consumers are aware of hygienic life style and there is a necessity of textile product with antimicrobial properties. There are a lot of new ideas that can come up in this multidisciplinary area.

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